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Air Brake System Evaluation of an Overlength Double Combination Vehicle

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Air Brake System Evaluation of an Overlength Double Combination Vehicle

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ABSTRACT

The test and demonstration of three overlength combination vehicles to the Ontario Commission on Truck Safety by MTC and the trucking industry indicated in part that the service air brake system performance of these vehicles was less than ideal. At present there is no combined vehicle air brake timing standard, Federal or Provincial, for articulated commercial vehicles.

Air brake timing system evaluation on a combination vehicle by MTC in co-operation with the trucking industry, a pilot test on which this report is based, indicates that much can be done by a combination vehicle operator to improve service air brake system response times. The addition of supplemental air valves, such as fast-acting relay and quick release valves can do much to achieve a more desirable air brake system operation. Similarly, the removal of self-storing service air lines can improve system response. Other factors relevant to improving system response were also identified in this pilot test and their effect on air brake system response will be investigated in other studies.

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1/ INTRODUCTION

The use of combination vehicles, A-trains and B-trains by the trucking industry is becoming more prevalent in order to provide an economical means of transporting consumer goods. The testing of several overlength combination vehicles of 30 to 35 m (100 to 115 ft) in length proposed by industry to enhance productivity [1], revealed that air brake system performance of these vehicles was less than ideal.

Both MTC and Industry, in an effort to promote the safe operation of all commercial vehicles, have undertaken a programme to evaluate air brake systems on existing tractor and trailer combinations. The data gained from this programme will provide the basis to better understand the current air brake system operational standards for on-the-road vehicles and how they can be modified if need be to further the safe operation of commercial vehicles.

2/ AIR BRAKE SYSTEM EVALUATION

The combination vehicle used for this test was provided by International Carriers Limited (ICL) of Woodstock, Ontario and consisted of two 1979 tandem axle trailers each 13.6m (45') in length, a single axle converter dolly and a 1982 conventional 6 x 4 tractor. All axles of the vehicle, 8 in total, were equipped with air brakes. The tractor had a dual system air brake arrangement and the trailers were plumbed to meet Federal CMVSS-121 air brake specifications. The trailers were equipped with automatic slack adjusters.

Air brake application times, 0 - 414 kPa (0-60 psig), and air brake release times, 655-35 kPa (95-5 psig) of the combination vehicles air brake system were monitored in both the "as-is" and modified conditions. Figure 1 shows the basic air brake system of the combination vehicle and indicates the axles being monitored.

During the vehicle inspection it was noticed that the original service air brake system plumbing of the tractor, dolly and trailers included many tees, elbows, adapters and other air line fittings of various sizes. The use of these fittings was no doubt for ease of system assembly by the original equipment manufacturer (OEM). The original plumbing on these vehicles was not changed except to install the supplemental air valves. Experience has shown however that air brake system timing can be adversely affected by overuse of such fittings.

2.1/ Push Rod Measurements (Millimeters)

The push rod travel was measured in the "as-is" condition, and initial brake application times were measured. The push rod travel was then set to minimum stroke by jacking each wheel or dual set clear of the ground, and adjusting the slack adjusters until a slight drag was felt when the wheel was turned.

Axle No.	Left Hand Side		Right Hand Side	
	"As-is"	Adjusted	"As-is"	Adjusted
1	35	17	33	17
2	30	30	35	32
3	40	30	40	37
4	30	21	25	19
5	30	28	25	25
6	43	35	47	38
7	30	22	28	20
8	34	27	34	22

The reduction in push rod travel ranged from 0% to 51% with an average of 24% for the vehicle. The reduction in push rod travel did not significantly affect air brake application timing on the trailers or the dolly. However the reduction of push rod travel on the tractor reduced application times of axle 1 and axle 3 by 22%. All trailer axles were equipped with automatic slack adjusters, while the tractor was equipped with manual slack adjusters.

While the adjustment of the push rod travel brought the mechanical components of the air brake system to an optimum level of operation, it did little to improve the brake timing of this particular vehicle.

2.2/ Application Timing: 0 to 414 kPa (0 to 60 psig)

The air brake system of the combination vehicle was connected to a regulated source of shop air set at 689 kPa (100 psig). When air pressure in the air brake system stabilized, application times were monitored, measured from first movement of the treadle valve. Application times were monitored with the slack adjusters in the "as-is" condition and in the "fully adjusted" condition. It was decided to evaluate the combination vehicle using the "fully adjusted" condition as reference. All application timings are shown in Figure 3.

The dolly was equipped with a Sealco 3100 mini-valve, S1, Figure 2, installed by ICL, with the intent that it would speed up application and release times of the dolly and second trailer. The timings for this condition are shown by (1), the reference condition.

The brakes and Sealco valve on the dolly were bypassed to examine their effect on the last trailer; the timings are shown by (2). It can be seen that not only was axle 8 affected (22%), but axle 5 was also noticeably slowed, (31%).

A Sealco 3100 mini-valve, S3, was added at the tractor and connected to the secondary air system, the intent being to accelerate the application air signal to the trailers. The valve and brakes at the dolly were also reactivated. The timings for this condition are shown by (3). It can be seen that timings were reduced for axle 5, 14%, and axle 8, 7%, from condition (1).

The tractor was equipped with a self-storing Synflex service air line. Previous experience showed that this type of air line affected timing [2] and it was replaced with a conventional rubber hose type service air line. Condition (4) shows the resulting application times. Axle 5 had a further timing reduction of 12% and axle 8, 9%, with respect to condition (3).

Another Sealco 3100 mini-valve, S2, was added to the service air system on the lead trailer to accelerate the air signal from this trailer to the dolly and second trailer. The timings are shown in condition (5). The application times

for axles 5 and 8 were reduced a further 21% and 18% respectively compared to condition (4). When compared to condition (1), application times were significantly reduced; axle 5 by 40%, axle 6 by 41%, and axle 8 by 28%.

The Sealco 3100 mini-valve on the dolly, S1, was bypassed in an attempt to reduce the spread in application times between axles 5, 6 and 8. The results, shown by condition (6), were such that the timing to axle 6 was increased to bring its activation time somewhat closer to axle 8 but the overall application timing spread was not reduced. Lack of time precluded further experimentation.

It can be seen from the various application times of the lead trailer, dolly and second trailer, that it is possible to accelerate the response times of the air brake system of a combination vehicle by the judicious use of supplemental air brake valves. The Sealco 3100 mini-valve chosen by ICL acted as an air signal accelerator, reducing the time required to charge a given volume of air line in order to activate the OEM relay valves. In most cases the installation of the mini-valve used in this vehicle evaluation was at best of the "jury-rig" nature. Had the installation of the valve(s) been optimized it is felt that the decrease in application times would have been greater than those observed in this test.

It should be noted in Figure 3 that the application times for the tractor were not significantly affected by the plumbing modifications made to the trailers and dolly. This can be attributed to the dual system design with which the tractor was equipped. It can be also seen that axle 1 always begins brake application after axle 3. This is the desired case in order to maintain vehicle (tractor) stability.

Figure 4 shows two examples of air brake application times; the reference condition (1) and the best "modified" condition, condition (5). The lag time for each axle is noticeable. Lag time is the time required for the service line, normally at 0 psig, to reach sufficient pressure to cause the relay valve to operate and pressurize the air brake chamber. In condition (1) the lag time is quite long for axles 5, 6, and 8.

The service lines are being only charged via the treadle valve which in turn is supplied by the tractor secondary air brake system reservoir. As the volume of air line is filled and pressurized the amount of available reservoir pressure drops, the signal velocity and strength also drops. This drop in signal strength is evident in the length of time required for the air chamber to reach 414 kPa (60 psig) from the time of first evidence of pressure at the air brake chamber.

In condition (5) the lag times to axles 5, 6 and 8 are much shorter. Similarly the pressure rise times are also shorter than in condition (1). The addition of the Sealco 3100 mini-valves S2 and S3 to both the tractor and lead trailer in effect divided the service air line volume into shorter sections each supplied by a relay valve having its own air reservoir. The activation of the treadle valve in turn activated S3 which in turn activated S2 and S1. At no time was there a significant loss of signal strength or velocity as was the case in condition (1). As each mini-valve became active the application signal was "boosted" and this stronger signal in turn caused the original equipment relay valves to respond faster and pressurize the air brake chambers to 414 kPa (60 psig) in a noticeably shorter time. The overall effect is a combination vehicle having more acceptable air brake application times than was originally the case.

2.3/ Exhaust Timing: 655 to 35 kPa (95 to 5 psig)

Achieving uniform application pressure levels at all axles in a reasonable amount of time proved to be difficult. The time required for the complete service air brake system to stabilize at 655 kPa (95 psig) was excessively long even with the vehicle connected to shop air. The "at level" method of starting the exhaust timing from first movement of the treadle valve, was dismissed. Instead application pressure levels were made in excess of 655 kPa (95 psig) and timing was started when the air pressure first fell through the 655 kPa (95 psig) level at a monitored axle.

The steering axle of the combination was used as the zero time reference, and all monitored axles were timed from this zero time reference until their air pressure level reached 35 kPa (5 psig). In addition, since the maximum application pressure for each axle varied slightly, the time required for the pressure level at each axle to fall from the maximum application pressure to 655 kPa (95 psig) was subtracted from the total elapsed response time of that axle to give the final exhaust time for each axle monitored.

It can be seen in Figure 5 that the exhaust times for the tractor, axles 1 and 3, were not significantly influenced by the plumbing changes introduced into the vehicle. The trailers and dolly generally exhausted applied air brake pressure to 35 kPa (5 psig) from 1.1 to 2.3 seconds later than the tractor depending upon the axle monitored and the valves in use. The most significant component change to degrade exhaust times was the removal of the Sealco 3100 mini-valve, S2, installed at the rear of the lead trailer. Axles 5, 6 and 8 had exhaust times increased by 45%, 50% and 36% respectively.

The replacement of the original spiral (self-storing) Synflex gladhand service air line between the tractor and lead trailer increased the exhaust times of axles 5, 6 and 8 by an additional time average of 6%.

The removal of valve S3 did not further degrade the exhaust response of the air brake system on the trailers and dolly, but rather shortened the exhaust times by an average of 2.6%. The reason for this is unknown.

Figure 6 illustrates the difference between the exhaust times of the combination vehicle in condition (1) the reference condition, and condition (5) the fully modified condition. The supplemental valving and gladhand hose change significantly reduced both the lag time and air brake chamber exhaust times.

The use of supplemental valving significantly improved the response times of the air brake system on the combination vehicle, as seen in the application timing tests. The Sealco 3100 mini-valve also acted as a quick-release valve during system exhaust. In effect the pressure in the volume of service air line controlled by the supplemental valves was reduced to that at atmosphere more rapidly. This allowed the relay valves in turn to release application pressure at the brake chambers sooner resulting in reduced air brake exhaust times.

The removal of the non-spiral tractor gladhand hose, condition (4) and replacement with a self-storing Synflex air line condition (3) had the following result:
The exhaust times of axles 5, 6 and 8 were increased by an average 6%. This increase in exhaust time reinforces the finding that spiral or self-storing air lines provide a restriction to service air brake signals. The exhaust times for the tractor were not affected.

2.4/ Air Reservoir Pressure Levels

The amount of air pressure available to activate the service brakes on the combination vehicle was varied to evaluate this influence on air brake application timing. The reservoir air pressure levels were varied from 586 kPa (85 psig) to 827 kPa (120 psig). The application times at these various pressure levels are shown in Figure 7. Referring to axles 3 and 8, it can be seen that the application times increased by 50% and 21% respectively between the maximum and minimum air reservoir pressure levels used for this test. The exhaust timing for the combination vehicle was not affected.

The tractor used in the test had its air compressor governor cut-in level set at 689 kPa (100 psig) and cut-out level set at 813 kPa (118 psig). The effect of this pressure variation increased application times for axle 3 by 13% and axle 8 by 8% between cut-in and cut-out air pressure levels.

Figure 8 shows the results of other air brake timing tests undertaken by MTC [2] in which reservoir air pressure level was varied and the resulting application times monitored on the rearmost axle of an 8 axle vehicle. It can be seen that if the spread between compressor governor cut-in and cut-out level settings is kept to a minimum and levels above 689 kPa (100 psig) are selected, reservoir air pressure levels will not significantly affect air brake application timing.

3/ CONCLUSIONS

It is difficult to manufacture an air brake system for a combination vehicle that will have sequential braking, the rearmost axle of the vehicle activating first and the remainder activating in sequence moving toward the front of the vehicle. The next most desirable condition of having all of the braked axles activate simultaneously is also difficult to achieve.

Air brake system operation is vulnerable to the domino effect. If one component of the system is either improved or degraded, the remainder of the system is usually similarly affected. Apart from erratic application, poor air brake timing can cause abnormal wear of brake shoes, brake drums and other foundation components on a specific axle that is doing more than its share of work while slowing the vehicle.

Excessive lag time between tractor and trailer, and between the trailers themselves, could possibly promote a dynamic imbalance in the vehicle while braking. This imbalance could lead to the loss of vehicle stability. By using supplemental valving it is possible for the operator of combination vehicles to improve the air brake system operation of these vehicles, reduce the possibility of vehicle instability, and reduce abnormal brake component wear.

ACKNOWLEDGEMENT

This test was undertaken with the assistance of ICL who provided the overlength combination vehicle, the facility in which the test was done and the mechanic who worked on the vehicle. Mr. James Rylance acted as co-ordinator for ICL on this project.

Data recording was done and analytical input was provided by Mr. Wm. Stephenson of MTC. Mr. Norman Carlton, also of M.T.C. provided technical assistance.

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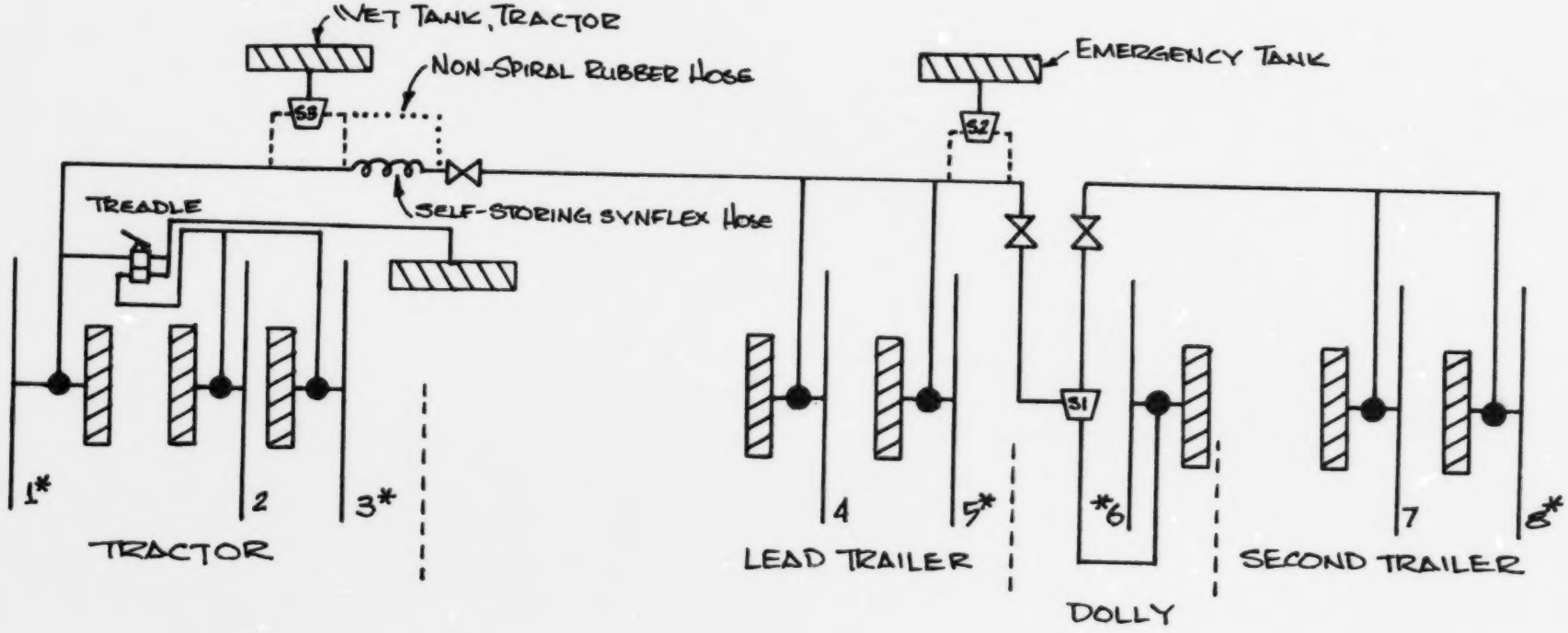
[1] Mercer, W.R.J., Billing, J.R., Wolkowicz, M.E., "Test and Demonstration of Double and Triple Trailer Combinations" MTC Transportation Technology & Energy Report TVS-CV-82-109.

[2] Wolkowicz, M.E., Stephenson, W., "Commercial Air Brake Vehicle Timing: A Specification Evaluation" MTC Policy Planning & Research Division Report CVOS-TR-80-04.



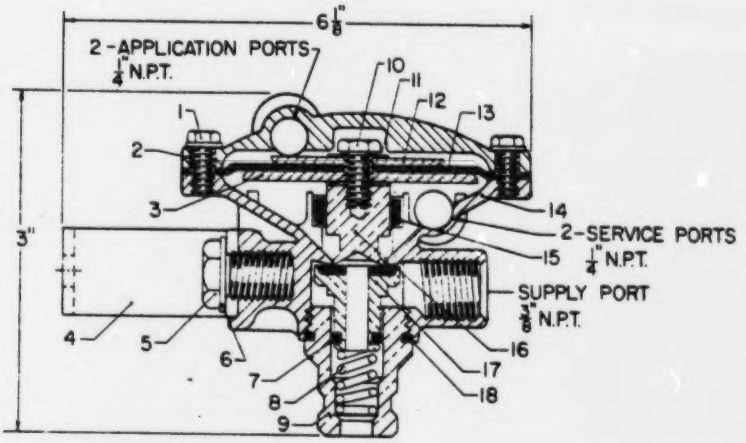
● - RELAY VALVE, ORIGINAL EQUIPMENT
Ⓢ - SEALCO 3100 MINI-VALVE
⋈ - GLADHAND HOSE COUPLING
* - MONITORED AXLE
▨ - AIR RESERVOIR

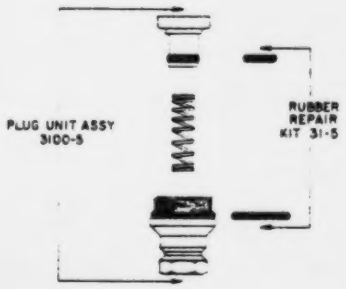
Fig. 1 - AIR BRAKE SYSTEM SCHEMATIC

AIR SEALCO CONTROLS

Mini-Valve

NO. 3100





No.	Quan.	Pc.No.	Description
1	6	206	CAP SCREW
2	1	0144	COVER
3	1	791	DIAPHRAGM PLATE
4	1	818	BRACKET
5	1	204	BOLT
6	1	120	LOCK WASHER
7	1	522	"O" RING
8	1	416	SPRING
9	1	719	LOWER BODY
10	1	201	BOLT
11	2	302	GASKET
12	1	781	DIAPHRAGM PLATE
13	1	528	DIAPHRAGM
14	1	22	HOUSING
15	1	1000-9	SNUBBER ASSY.
16	1	711	ACTUATOR
17	1	591	MOVABLE SEAT
18	1	519	GASKET

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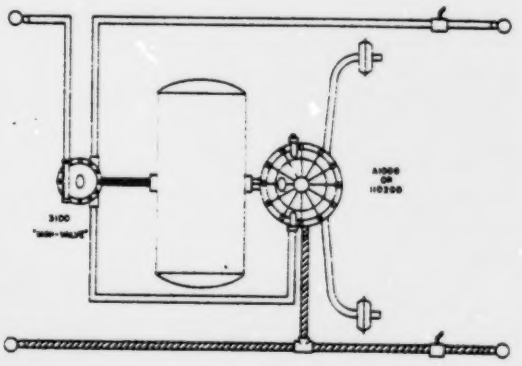
or Repair with
No. 31-5 Kit

A special purpose valve designed for speed-up of application and release of brakes to rearmost trailers in doubles or triples combination. Greatly reduces jack-knifing tendencies.



DOLLY CONVERTER PIPING

Fig. 2: SEALCO 3100 MINI-VALVE

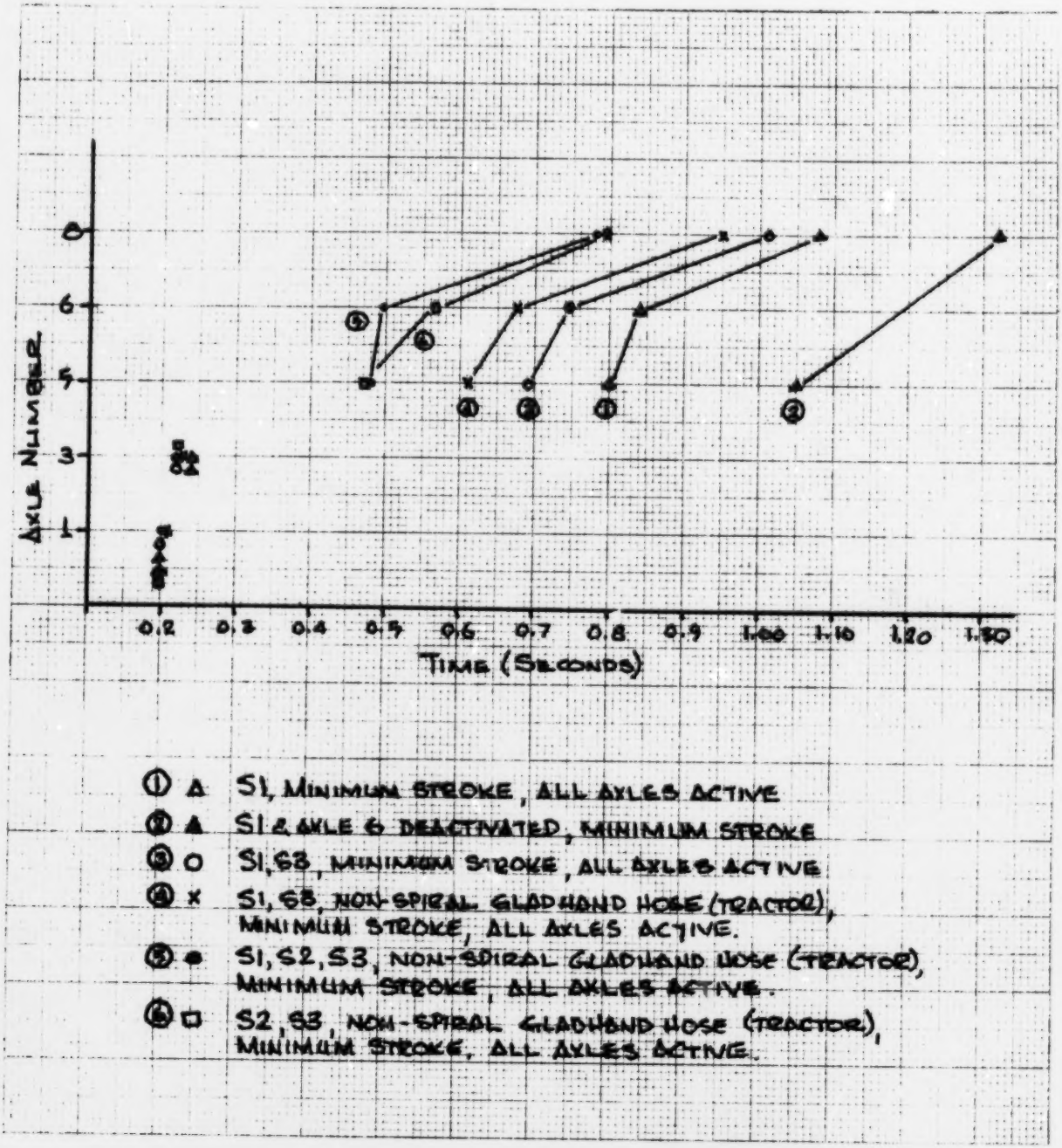


Fig. 3 AIR BRAKE APPLICATION, 0 TO 414 kPa (0 TO 60 psig) @ 689 kPa (100 psig) RESERVOIR PRESSURE.

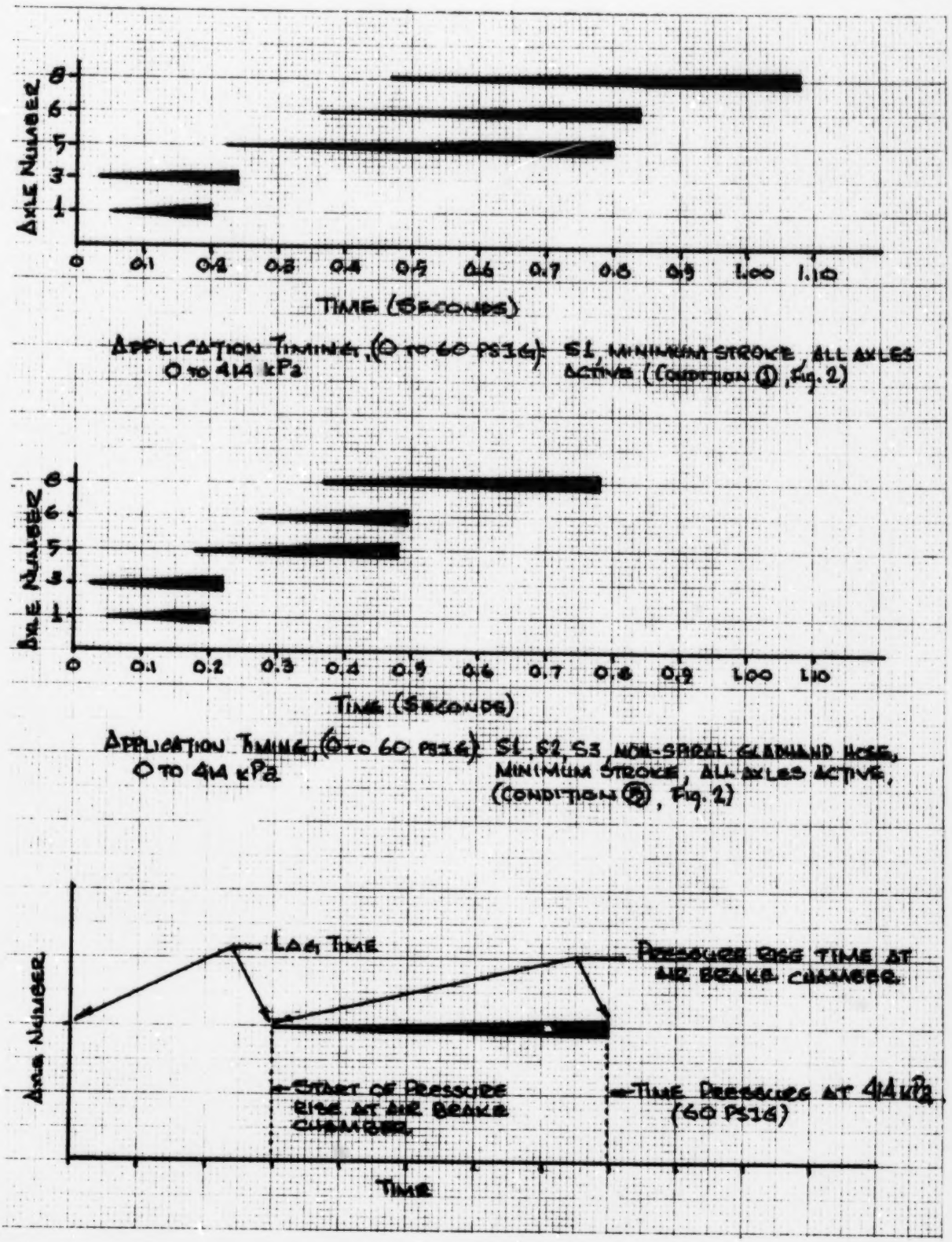
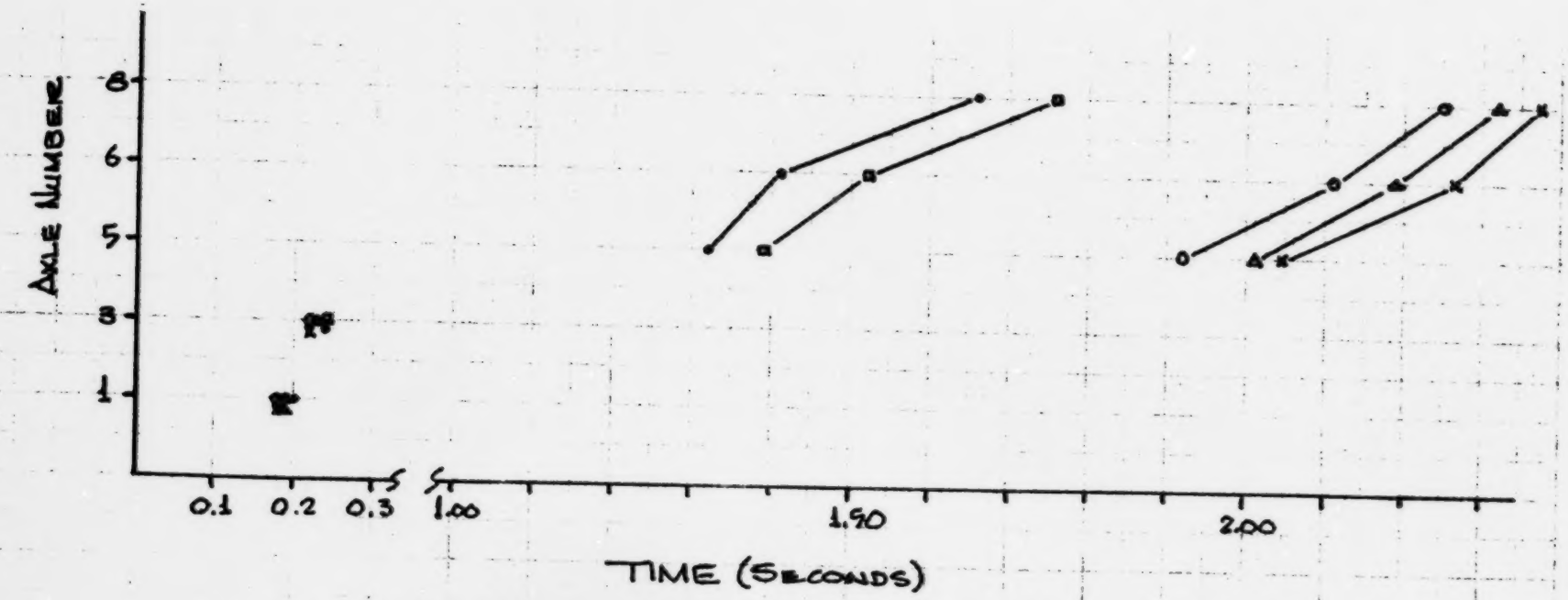


Fig. 4 AIR BRAKE APPLICATION SEQUENCE



△ CONDITION ①; S1, MINIMUM STROKE, ALL AXLES ACTIVE
○ CONDITION ③; S1, S3, MINIMUM STROKE, ALL AXLES ACTIVE
× CONDITION ④; S1, S3, NON-SPIRAL GLADHAND HOSE, MINIMUM STROKE, ALL AXLES ACTIVE.
● CONDITION ⑤; S1, S2, S3, NON-SPIRAL GLADHAND HOSE, MINIMUM STROKE, ALL AXLES ACTIVE.
□ CONDITION ⑥; S2, S3, NON-SPIRAL GLADHAND HOSE, MINIMUM STROKE, ALL AXLES ACTIVE.

Fig. 5 AIR BRAKE SYSTEM EXHAUST TIMING, 655 TO 35 kPa (95 TO 5 psig)

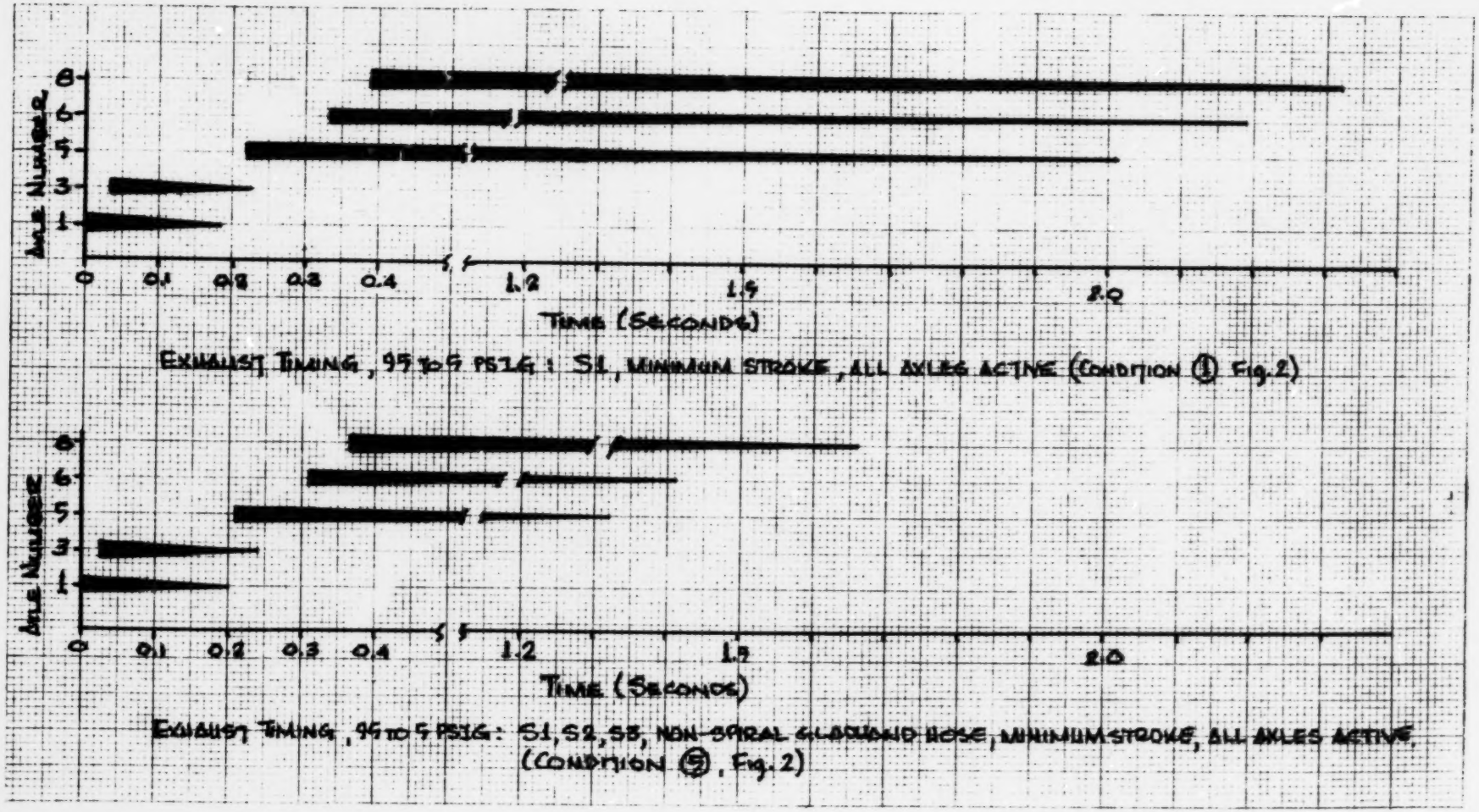


Fig. 6 EXHAUST TIMING: LAG TIMES @ 655 TO 35 kPa (95 TO 5 psig)

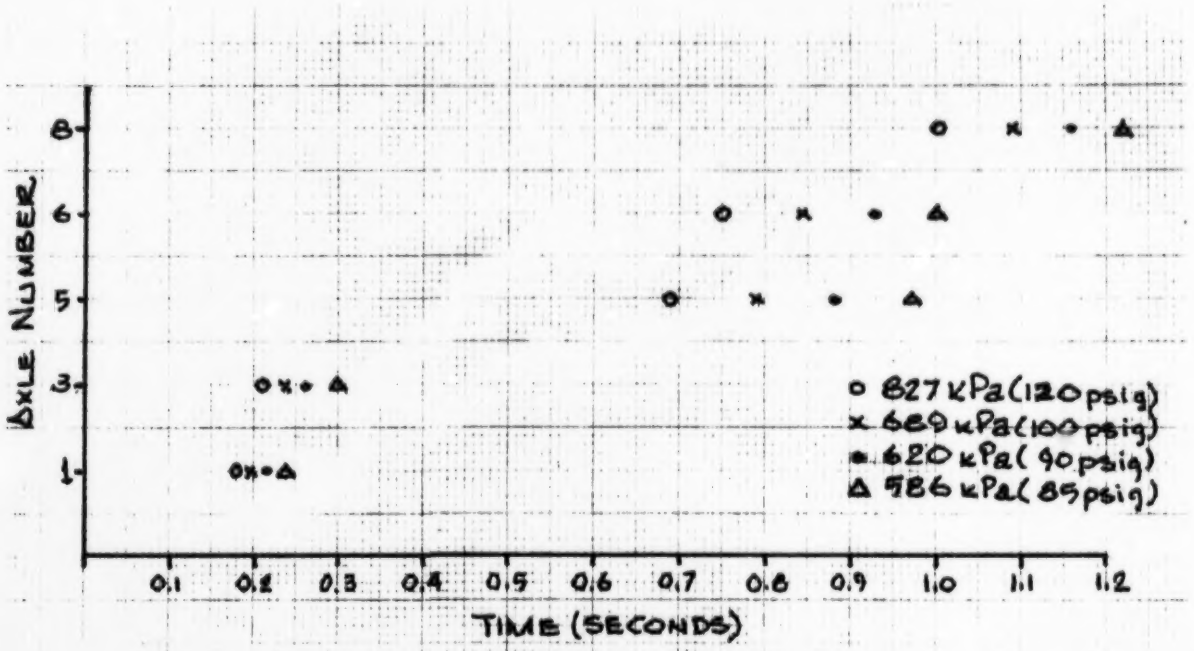


Fig. 7 APPLICATION TIMES 0-414 kPa (0-60 psig), VARIOUS RESERVOIR PRESSURES, SLACK ADJUSTERS AT MINIMUM STROKE

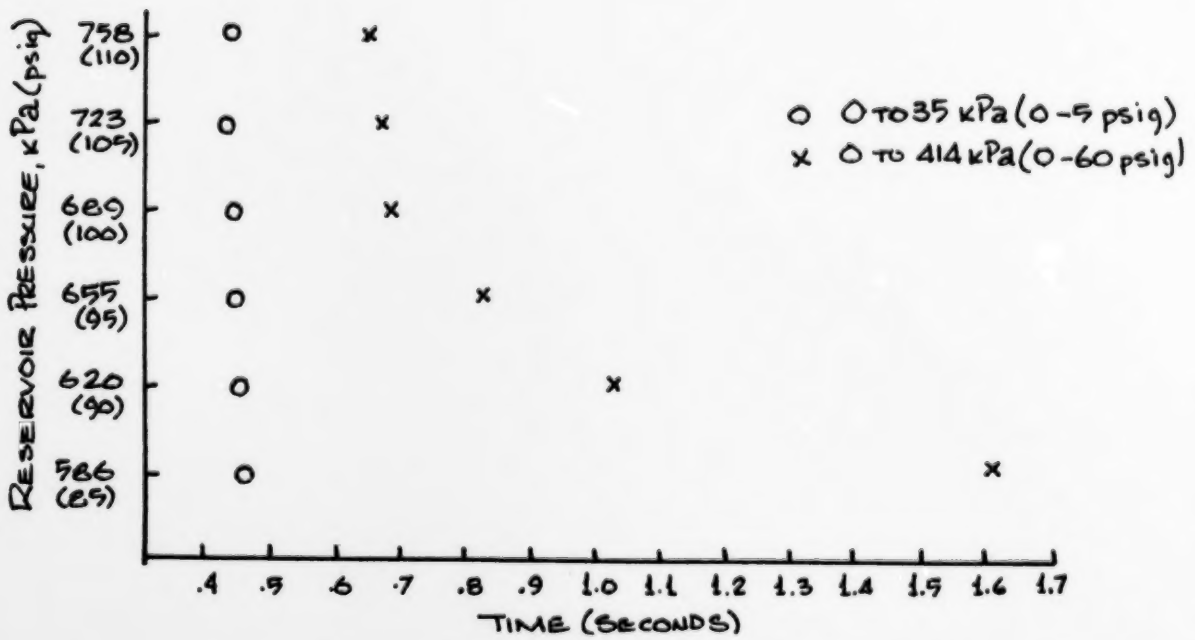


Fig 8: RESERVOIR PRESSURE VS. APPLICATION TIME

POOR

QUALITY

ORIGINAL